All of the information in this report is preliminary and subject to further evaluation. Information may not be published or quoted without the permission of the Project Director. Manipulation of these data beyond what is contained in this report is discouraged.

PROJECT DESCRIPTION

The goal of this study is to evaluate and demonstrate the effects of sage-grouse friendly livestock grazing strategies, created by the Natural Resources Conservation Service (NRCS), on the population dynamics of greater sage-grouse (*Centrocercus urophasianus*; hereafter sage-grouse) as well as sage-grouse habitat. To this end, we monitor sage-grouse adult females (hereafter hens) on Sage-grouse Initiative (SGI) contracted lands and compare these data with data from hens that we monitor on areas where there are no SGI grazing systems (non-SGI areas). In addition, in 2014 our study area has been extended to the Lake Mason National Wildlife Refuge (NWR; hereafter the Refuge), which is adjacent to our study area. On the refuge we measure habitat and monitor for the presence of our marked hens. We have completed 5.5 years (corresponding with 5.5 years since the initiation of SGI on our study area) of this 10 year study. This report includes information beyond the reporting period regarding the entire project and study area as well as progress specific to the Refuge during all years of the study (2011 – 2016). Data from the 2016 season is still being collected and entered and will not be represented in results. Work completed for the entire study during the reporting period (2016) includes capturing and marking hens with radio transmitters, finding and monitoring nests of marked hens, capturing and marking sage-grouse chicks with radio transmitters, and measuring key vegetation characteristics in sage-grouse habitat and among grazing treatments.

OBJECTIVES AND ALTERNATIVES

The short-term objective of this 1-year funding period was to study the direct effects of livestock grazing on vital rates of sage-grouse and on sage-grouse habitat in Musselshell and Golden Valley counties, Montana (MT; Fig. 1) during the 2016 field season. We continued the collection of data to help evaluate the effectiveness of SGI grazing systems as a habitat management tool for stabilizing or improving sage-grouse habitat and populations. We continued to monitor vegetation as well as the presence of any marked hens on the Refuge.

The goal of this study is to evaluate the effects of NRCS's SGI grazing strategies on sage-grouse vital rates and habitat. Taylor et al. (2012) has shown that adult female (hen) survival, nest success, and chick survival are the three most important drivers of population growth in sage-grouse populations. Therefore the goal of our project is to investigate the impacts of grazing on these vital rates. We are also monitoring the habitat use of hens and chicks, nest site selection of hens, and vegetation response to grazing, as well as investigating how habitat use links with vital rates. We are comparing these variables between SGI-enrolled and non-participating ranches (Non-SGI).

This study is designed as a 10-year study because the effects of grazing on habitat (and hence, sage-grouse) may exhibit a "lag" effect and may be tempered by the confounding effects of habitat, weather, and other variables. Some impacts of grazing management may be observable or fully realized only after several years. In addition, multiple years of data are needed to obtain enough sampling replicates of pastures within each grazing treatment for analyses and inferences. The study's duration also helps ensure that we obtain good estimates of sage-grouse population vital rates and their habitats despite annual fluctuation in these measures due to weather and other influences.

This project has the following long-term objectives (beyond the dates covered by this agreement):

1. Measure and compare the vegetation response in pastures among different

grazing treatments, relative to published sage-grouse habitat needs;
2. Measure individual vital rates known to impact population growth in sage-grouse and relate these estimated vital rates directly to habitat variables and other important drivers; and
3. Identify seasonal movements and resource selection by sage-grouse hens and chicks to quantify use of different grazing treatments proportional to habitat availability and other drivers of sage-grouse resource selection.

METHODS AND PROTOCOLS

We use radio telemetry to collect data on hen survival, nest success, chick survival, and habitat use. We collect vegetation data at nests and randomly selected sites in potential sage-grouse nesting habitat to measure the influence of vegetation and grazing treatments on sage-grouse nest success and nest site selection. We also collect vegetation data among grazing treatments to evaluate the effect of grazing on sage-grouse habitat. These treatments include: SGI-Rested, SGI-grazed, Non-SGI, and Refuge (Lake Mason satellite refuge units of the Charles M Russell NWR). Herein we report on results of analyses on data from vegetation response plots sampled across the study area.

CURRENT PARTNERS

Representatives from several other agencies/organizations have been involved with or provided support for this project.

- David Naugle, Associate Professor, Wildlife Biology Program, University of Montana (UMT) and Science Advisor, Natural Resources Conservation Service (NRCS)
- Justin Gude, Wildlife Research and Technical Services Chief, Montana Fish, Wildlife, and Parks (FWP)
- Catherine Wightman, Sagebrush, Wetland, and Farm Bill Coordinator, FWP
- Michael Frisina, Adjunct Professor, Department of Animal and Range Sciences, Montana State University (MSU)
- Bok Sowell, Professor, Department of Animal and Range Sciences, MSU
- Austin Shero, District Conservationist, NRCS, Roundup, MT
- Scott Anderson, Range Conservationist, NRCS, Roundup, MT
- John Carlson, T&E Program Lead/Conservation Biologist, Bureau of Land Management (BLM), Montana/Dakotas State Office
- Floyd Thompson, Rangeland Management Specialist, BLM, Montana State Office
- Brandon Sandau, Department of Natural Resources and Conservation
- Victoria Dreitz, Research Assistant Professor, Wildlife Biology Program, UMT
- Hayes Goosey, Research Scientist, Animal and Range Sciences, MSU
- Safari Club International Large Grants Program
- Big Sky Upland Bird Association
- FWP Upland Game Bird Enhancement Program

Collaborations:

- **Montana State University**. We collaborate with Research Scientist Dr. Hayes Goosey, Department of Animal and Range Sciences, Montana State University, on a concurrent study that leverages our relationships with landowners and established grazing treatments, and provides key data on food availability for greater sage-grouse hens and chicks in our study: "Effects of Grazing on Grouse Food Insect, Pollinator, and Dung Beetle Ecology". This is a new project that expands upon the previous work we did with this collaborator during 2012 – 2015.

- **University of Montana**. Ongoing collaboration (since 2012) with Dr. Victoria Dreitz, Assistant Professor, Wildlife Biology Program and Director, Avian Science Center, The University of Montana on a concurrent study that leverages our relationships with landowners and established grazing treatments: "Assessing Land Use Practices on the Ecological Characteristics of Sagebrush Ecosystems: Multiple Migratory Bird Responses" (Dreitz et al. 2015).

CURRENT SOURCES OF SUPPORT

Funder	Support
USFWS Inventory & Monitoring Funds	$95,862.77 over 6/1/14 – 5/31/19, plus time from refuge technicians
FWP license sale funds and matching Pittman-Robertson funds administered by the USFWS	$133,333 / year, 2013 – 2021
USBLM Grant/ Cooperative Agreement L15AC00097	$80,363 in 2015; $40,000 in 2016
Safari Club International Large Grants Program	$50,000 in 2017

PAST SOURCES OF SUPPORT

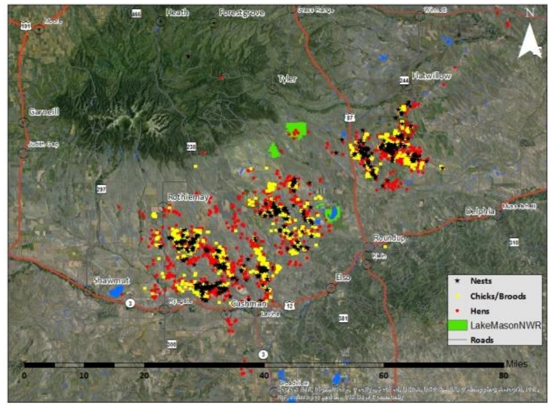
Funder	Support
NRCS Conservation Innovation Grants Program	$170,000 over 3 years (2011 – 2013)
Intermountain West Joint Venture / Pheasants Forever	$242,000 over 4 years (7/1/12 – 6/30/16)
NRCS Conservation Effects Assessment Project funds awarded to David Naugle at the University of Montana	$50,000 in 2011
FWP Upland Game Bird Enhancement Program	$43,000 over 3 years (2011 – 2013)
Big Sky Upland Bird Association	$1,000

CURRENT STATUS

Lake Mason Satellite Units

From March 2011 to October 2016 the North and Lake Mason units of the Refuge have had some winter and fall use by our marked sage-grouse, particularly the North unit (Fig. 1).

(a)



(b)

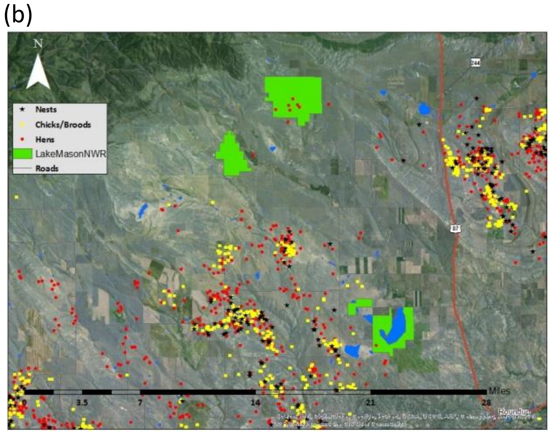
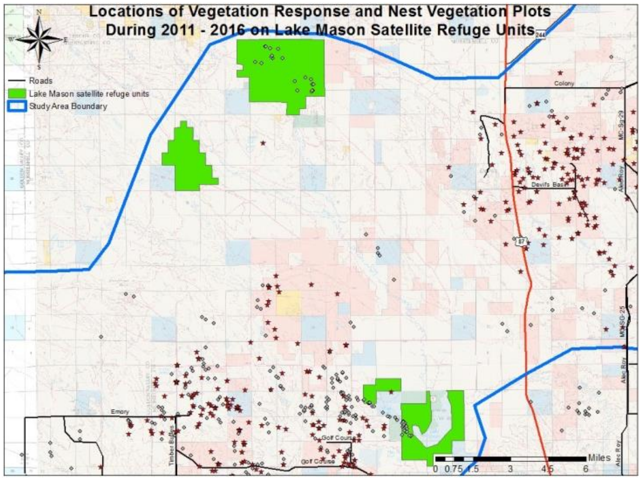


Figure 1. A map of grouse locations on the study area north of Lavina and north and west of Roundup, Montana, in Golden Valley (western portion) and Musselshell (eastern portion) Counties. (a) The entire study area. (b) A zoomed in view of the same map to show detail on the Lake Mason satellite refuge units. The maps include greater sage-grouse locations of hens, chicks/broods, and nests during the first 4.5 years of the study.

Vegetation

"Vegetation response plots" in this study are stratified random vegetation plots that we have used to assess the response of vegetation to different grazing treatments. During 2014 – 2016, we completed data collection at 34, 32, and 33 vegetation response plots, respectively, on the Refuge (Fig. 2a). We are using a repeated measures design to monitor changes in vegetation over time on the Refuge and thus sample the same plots each a)



b)

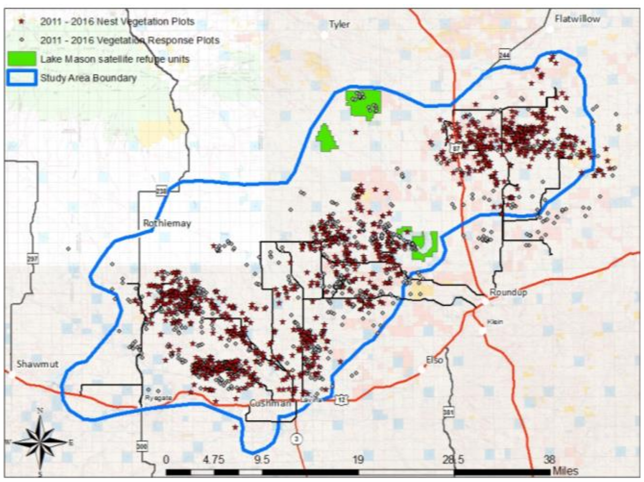


Figure 2. Locations of 2011 – 2016 nest vegetation and vegetation response plots for the greater sage-grouse grazing project in Musselshell and Golden Valley Counties, Montana (a) on the Lake Mason satellite refuge units and (b) on the entire study area. The light orange and pink polygons represent BLM lands, the light blue polygons represent State lands, and white polygons represent private lands.

year. The difference in the number of sample plots each year is due to how much effort we could put into sampling in that particular year. In 2015, we were able to measure 32 randomly chosen plots of the original 34 we sampled in 2014, and in 2016 we were able to sample 33 of the original plots. These plots represent a baseline for vegetation before grazing because grazing has been absent from the Refuge for several years.

For the entire study area during 2011 – 2016 we completed 1,191 vegetation response plots and 1,327 “nest vegetation plots” at nests and random points stratified to be within potential nesting habitat to evaluate nest site selection by hens (Fig. 2b). There were no sage-grouse nests on the Refuge; the nest vegetation location that appears on the border of one of the Refuge units (Fig. 2) is a random nest vegetation plot that is on the state section just south of that unit.

<u>Vegetation Response to Grazing Results: 2012 – 2015</u>

The following results apply to the entire study area rather than the Refuge alone.

We use herbaceous vegetation measurements at a set of stratified random field plots among grazing treatments to test for differences in indicators of habitat quality across the project area. In 2012 we sampled field plots on both SGI and Non-SGI using a variety of grazing techniques. These data were then used to parameterize a power analysis to develop a sampling scheme for subsequent field seasons. We identify pastures rested each season and sample an appropriate number of field plots in grazed SGI pastures, rested SGI pastures, and Non-SGI pastures to test for differences in vegetation structure among these treatments. Rangelands are highly dynamic and spatially heterogeneous and assessing their condition over large areas has always been a logistical challenge (West 2003). We use ArcGIS (ESRI Inc., Redlands, CA) and program R (R Core Team 2011) to generate stratified random points using the criteria in Table 1. Local-scale vegetation plots measured in the field are centered on a random point and extend 15 m in each cardinal direction (“spokes”). Along each spoke we estimate visual obstruction using a Robel pole (Robel et al. 1970) at 1, 3, and 5 m from the random point. Using Daubenmire frames (Daubenmire 1959) at 3,

Variable	Acceptable Range	Data Source
Slope	0 – 5 degrees	10 m DEM (National Elevation Dataset)
Soil Type[1]	60C, 60D, 64A, 64B, 68C	NRCS SSURGO Database[3]
Distance to Water[2]	200 – 1500 m	Local NRCS records, National Hydrography Dataset[4]

[1]Soil map units chosen for inclusion are salty clay loams that typically support sagebrush in the study area.
[2]Field checked.
[3]http://soildatamart.nrcs.usda.gov
[4]http://nhd.usgs.gov

Table 1. Criteria for inclusion of sampling plots used to measure vegetation response to grazing systems.

6, and 9 m from the random point along each spoke we measure the grass height (maximum droop height with and without the influorescence, current year's and residual grass) and estimate percent cover of native and nonnative live (current year) grass, residual (previous year's or dead) grass, native and nonnative forbs (herbaceous flowering plants), litter (detached dead vegetation), lichen, moss, bare ground, rock, and cowpies. Starting in 2016, in each Daubenmire frame we record forb species and the number of individuals of each species to measure forb species diversity and abundance. Additionally, we measure distance to water as well as the four most dominant herbaceous species in the plot.

We used linear mixed effects models to test for grazing system and rest effects (fixed effects) on vegetation metrics while accounting for variation across years and ranches (random effects). Our years are defined as Apr 1 – Mar 31. For example, year 2012 in our report is defined as Apr 1, 2012 – Mar 31, 2013. We define "rest" as any pasture rested for 12 consecutive months. Linear mixed effects models were fit using the lme4 package (Bates et al. 2015) in program R. Significance of fixed effects was assessed with likelihood ratio tests, by comparing models with and without a fixed effect for grazing system.

We sampled 353 vegetation plots on Non-SGI ranches and 510 vegetation plots on SGI ranches during 2012-2015. Likelihood ratio tests indicated that live grass height (χ^2 = 9.4, df = 1, p = 0.002), residual grass height (χ^2 = 5.3, df = 1, p = 0.021), bare ground (χ^2 = 4.9, df = 1, p = 0.027), and litter (χ^2 = 6.6, df = 1, p = 0.010) all differed between Non-SGI and SGI ranches.

Visual obstruction (χ^2 = 0.22, df = 1, p = 0.642) and herbaceous vegetation cover (χ^2 = 0.27, df = 1, p = 0.605) did not differ between grazing systems (Fig. 3). After accounting for grazing system effects, the

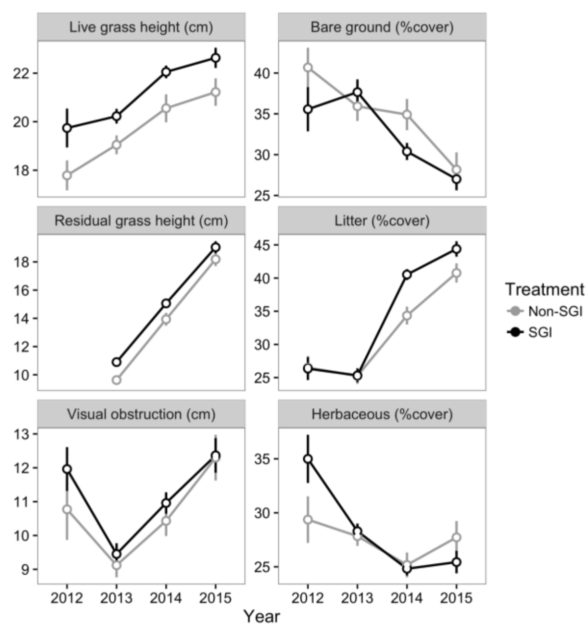


Figure 3. Means and standard errors of vegetation metrics measured at vegetation response plots on ranches enrolled in Sage Grouse Initiative (SGI) rotational grazing systems and on non-enrolled (Non-SGI) ranches in Golden Valley and Musselshell Counties, Montana, USA during 2012 – 2015. Likelihood ratio tests revealed that live grass height, residual grass height, bare ground cover, and litter cover all differed significantly between SGI and Non-SGI ranches. Estimated effect sizes were small, however, relative to annual variation.

effect of pasture rest was negligible and non-significant for all variables tested. Grazing system effect sizes, however, were small relative to annual variation: live grass height was 1.50 cm (SE 0.467 cm) greater on SGI ranches, residual grass height was 1.04 cm (SE 0.432 cm) greater on SGI ranches, bare ground cover was 6.05% (SE 2.695%) lower on SGI ranches, and litter cover was 4.52% (SE 1.762%) higher on SGI ranches.

Nest Site Selection Results: 2011 – 2015

We collect location data on adult sage-grouse hens and sage-grouse chicks marked with radio transmitters to assess (1) seasonal resource selection by adult hens, (2) nest site selection by adult hens, and (3) resource selection by hens with broods or by marked chicks. We are currently in our 6th year of data collection and herein report preliminary results for nest site selection from 2011-2015. We are currently working on data analyses for resource selection by hens and chicks and these will be completed outside of the time period for this agreement.

Nests are found by monitoring hens marked with radio transmitters. To evaluate the effects of vegetation on nest success and nest-site selection, we sample vegetation at nests as well as stratified random points within potential nesting habitat. We use ArcGIS and program R (R Core Team 2011) to generate random points that are constrained to be within 6.4 km of leks, not in cropland, and in a sagebrush-dominated land cover. Nest plots are measured after nests have reached their estimated hatch date (for failed nests) or after the nests successfully hatch. Plots at random points are measured during the same week as nest plots that are in the same area. Local-scale vegetation plots measured in the field are centered on the nest bowl or a random shrub (the shrub nearest to a random point and >35 cm in height) and extend 15 m in each cardinal direction ("spokes"). Much of our protocol for sampling vegetation follows the procedure outlined in Doherty (2008). At the nest or random shrub we measure grass height (maximum droop height with and without the influorescence, current year's and residual [previous year's] grass); the top two dominant cover species of grass; height, width, species, and percent vigor of the nest or random shrub; and visual obstruction using a Robel pole (Robel et al. 1970). Along each spoke we estimate visual obstruction at 0, 1, 3, and 5 m from the nest or random shrub. Using Daubenmire frames (Daubenmire 1959) at 3, 6, and 9 m from the nest or random shrub along each spoke we measure the height of the nearest shrub; measure the grass height (maximum droop height with and without the influorescence, current year's and residual grass); and estimate percent cover of native and non-native live (current year) grass, residual (previous year's or dead) grass, native and non-native forbs (herbaceous flowering plants), litter (detached dead vegetation), lichen, moss, bare ground, rock, and cowpies. Starting in 2016, in each Daubenmire frame we record forb species and the number of individuals of each species to measure forb species diversity and abundance. For each spoke we also measure sagebrush canopy cover and density using line-intercept and belt transect methods (Canfield 1941; Connelly et al. 2003). Additionally, we measure an index of livestock utilization in each local-scale vegetation plot by measuring the percent of the plot that has been grazed and counting the number of cowpies (both from the current and previous year) in each plot. These data enhance the information we obtain from NRCS and landowners on the grazing history in specific pastures.

In addition to collecting local-scale vegetation data, larger scale vegetation and other habitat data (e.g., distance to roads) are measured using remote sensing data from GIS layers for evaluating landscape-scale variables that may impact nest site selection and nest success of hens. We collected data on precipitation each year from the Oak Ridge National Laboratory Distributed Active Archive Center, a data center of the National Aeronautics and Space Administration's Earth Observing System Data and Information System (<https://daymet.ornl.gov/>).

We used Bayesian methods to fit logistic regression models relating measured covariates to the probability that a site was a nest (1) versus a randomly sampled available site (0). We used indicator variables paired with each model coefficient to assess variable importance and produce model-averaged coefficient estimates (Kuo and Mallick 1997). We performed an initial screening of variables by fitting univariate nest site selection models to each candidate variable and rejecting variables when 85% credible intervals for coefficients overlapped zero. Of the 16 variables passing variable screening, seven were supported with Bayes factors ≥ 3 (Fig. 4). These were nest shrub volume, plot-scale (15 m) sagebrush cover, patch-scale (100 m) roughness, patch-scale sagebrush heterogeneity, distance to county roads and highways, distance to two-track roads, and proportion of the landscape (1.61 km) disturbed. At the scale of the nest substrate, females selected shrubs with greater volume. At the plot scale, females selected for greater sagebrush cover. At the patch scale, females selected gentler terrain and more even stands of sagebrush. Finally, females preferred to locate nests farther from county roads and highways but closer to two-track roads, and avoided landscapes with greater amounts of non-cropland anthropogenic disturbance. We do not have a clear biological interpretation of selection of nest sites closer to 2-track roads. We speculate that this preference may reflect the tendency for 2-track roads to traverse terrain preferred by sage- grouse for nesting, e.g., areas of gentle topography. We found no evidence of selection with respect to herbaceous vegetation metrics, current-year's livestock use intensity, or density of previous-years' cow pats.

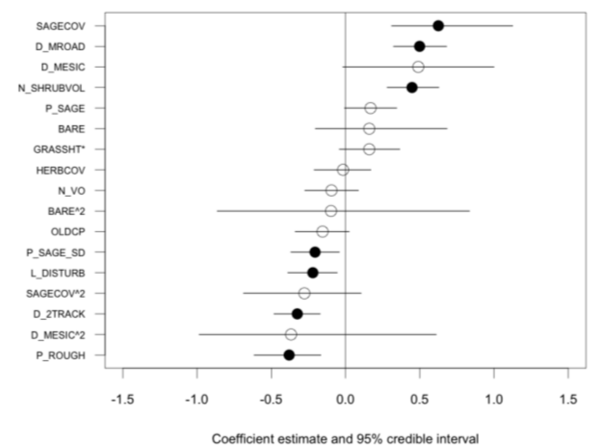


Figure 4. Coefficient estimates from a logistic regression model describing variables influencing the selection of nest sites (n=322) by sage-grouse in Golden Valley and Musselshell Counties, Montana, USA from 2012 to 2015. Filled circles identify variables supported by Bayes factors and error bars represent 95% credible intervals. Selection of nest sites was driven not by herbaceous vegetation characteristics but by preference for greater shrub cover (SAGECOV) and size (N_SHRUBVOL), gentle topography (P_ROUGH), avoidance of county roads and highways (D_MROAD), and avoidance of non-cropland anthropogenic disturbance at the landscape scale (L_DISTURB).

VITAL RATES

Hen Survival: 2011 – 2015

We collect data on sage-grouse vital rates including hen survival, nest success, and chick survival each year and are currently in our 6th year of data collection. Herein we report preliminary results for nest success with respect to habitat variables. We also report preliminary survival analyses of hens and chicks, but we have not yet related these two vital rates to habitat variables. These analyses will be completed outside the time period of this agreement.

We maintain 100 hens marked with radio transmitters in our marked population each year. We typically capture and mark hens at the start of the breeding season each spring during March – April to replace hens that died in the previous year. Hens are captured on or near leks using night-time spotlighting (Giesen et al. 1982), one of the most common and safe methods of capture. Hens are fitted with 22 g necklace style very high frequency (VHF) radio transmitters (Model A4060, Advanced Telemetry Systems, Isanti, MN), measured, weighed, and released. Yearling females captured during our study have a mean weight of 3.5 lbs (standard error of the mean [SE] = 0.02), and adult females have a mean weight of 4.0 lbs (SE = 0.01). A 22 g radio transmitter is ~1.4% of the body weight for a 3.5 lb yearling female, 1.2% for a 4 lb adult female, and lasts 434 to 869 days (1.2 – 2.4 yrs). The transmitters have a mortality switch on-board that is activated when the transmitter has been motionless for at least 4 hrs. We attempt to recapture hens at 2 yrs after initial capture to replace old transmitters with new ones before the old transmitter batteries expire. In this way we attempt to monitor individual hens as long as possible. This population of sage-grouse is not migratory and can be monitored continuously within the study area. We monitor marked hens from April through August from the ground with the help of seasonal field technicians each year who obtain at least two locations for each hen per week. During September through March we monitor the hens via aerial telemetry once per month.

Our annual survival estimates of hens are measured from Apr 1 – Mar 31 each year. Apparent annual survival estimates (number of hens alive at the end of the monitoring period / total number of hens alive at the start of the monitoring period) during 2011 – 2015 ranged from 57 – 82% (Table 2). Our annual

Year / Season	Apr-May (Spring)	Jun-July (Summer)	Aug – Oct (Fall)	Nov – Mar (Winter)	Annual
2011	88%	91%	90%	79%	57%
2012	84%	93%	89%	82%	82%
2013	93%	86%	90%	89%	67%
2014	91%	100%	79%	98%	75%
2015	95%	98%	96%	78%	77%
2016	89%	94%	85%	In progress	In progress

Table 2. Apparent seasonal and annual survival (number of hens still alive / total number of hens monitored) of radio-marked greater sage-grouse hens in Golden Valley and Mussellshell Counties, Montana during 2011 – 2016 for both SGI and Non-SGI areas combined. We measure annual survival from Apr 1 – Mar 31.

survival estimates are comparable to those observed in other studies across the range of sage-grouse (Table 3), though we caution that the apparent survival estimates in Table 4 do not

Survival Estimate	Location	Reference
75 – 98%	Central Montana, our study area	Sika 2006
48 – 78%	Wyoming	Holloran 2005
48 – 75%	Idaho	Connelly et al. 1994
57%	Alberta	Aldridge and Brigham 2001
61%	Colorado	Connelly et al. 2011
37%	Utah	Connelly et al. 2011

Table 3. Summary of annual greater sage-grouse hen survival estimates from several studies across the greater sage-grouse range.

represent formal survival analyses. We have defined seasons to represent biologically meaningful separations *sensu* Blomberg et al. (2013; Table 2). There are few published seasonal survival estimates available for sage-grouse hens. We have slightly different definitions for our seasons than Sika (2006), but our apparent hen survival estimates are comparable to what Sika

(2006) observed on our study area during 2004 – 2005. Monthly survival from April to June was 94%. July survival during 2004-05 was 99% to nearly 100% each year, and August survival was 94% and 84% in 2004 and 2005, respectively. Our apparent seasonal survival rates are lower relative to seasonal survival estimates measured by Blomberg et al. (2013) in a Nevada population of greater sage-grouse. Again we caution that our annual rates are apparent estimates and Blomberg et al.'s (2013) are estimated using formal survival analyses. Blomberg et al. (2013) monitored hen survival for 328 hens from 2003-2011. Their seasonal survival estimates, represented here as mean survival ± standard error (SE) were: spring = 0.93 (93%) ± 0.02; summer = 0.98 ± 0.01; fall = 0.92 ± 0.02; and winter = 0.99 ± 0.01. Blomberg et al. (2013) found very little annual variation in hen survival, allowing them to pool seasonal estimates among years (above). Our seasonal rates appear more variable among years. We have yet to evaluate inter-annual variation in seasonal survival rates formally and thus present our rates by year.

We used Kaplan-Meier survival functions to estimate the overall survival of hens during 2011 – 2015. The Kaplan-Meier estimator measures the survival of individuals over a series of monitoring occasions, producing a survival function of cumulative survival through the monitoring period (Kaplan-Meier 1958, Cooch and White 2013). We used package "survival" (Therneau 2016) in program R to run Kaplan-Meier analyses. The Kaplan-Meier mean survival time estimate for all marked hens monitored from March 2011 – September 2015 is 1,091 days (2.98 yrs; standard error [SE] = 68.2 days; 95% confidence interval = 745 – 1,375 days or 2.04 – 3.77 yrs) and the median is 856 days (2.35 yrs; Fig. 5). These estimates include 300 hens and we used a staggered-entry design of individuals throughout the study period. We used right censoring for individuals with unknown fates, dropped transmitters, and individuals that survived until their transmitters expire. Thus our Kaplan-Meier survival estimates are conservative. For these estimates we pooled data across all years.

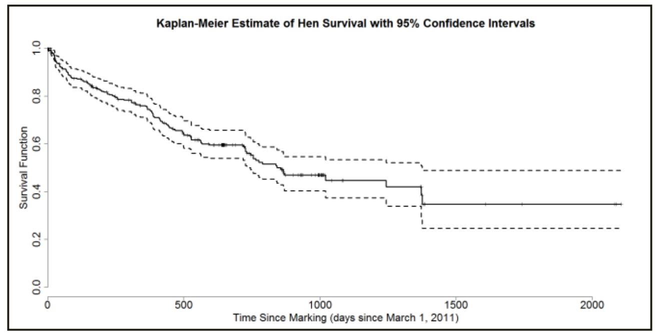


Figure 5. The Kaplan-Meier survival curve (solid line) and 95% confidence interval (dashed lines) for greater sage-grouse hens monitored from 2011 – 2015 in Golden Valley and Musselshell Counties, Montana.

Nest Success: 2011-2015

Nests are found by monitoring hens via radio telemetry and are monitored every other day until they fail or hatch (defined as at least one chick successfully hatching and leaving the nest). Annual apparent nest success (number of monitored nests that hatched at least one chick / total number of nests monitored) during 2011 – 2015 ranged from 30 – 64% (Table 4). The number of marked hens that attempted at least one nest each year ranged from 64 – 78% (Table 5).

We used Bayesian methods to fit logistic regression models relating measured covariates to daily nest survival rate. As with nest site selection models, we used indicator variables paired with each model coefficient to assess variable importance and produce model-averaged coefficient estimates, and performed an initial variable screening step, rejecting variables when 85% credible intervals for coefficients overlapped zero. We included separate intercepts for each year and a random effect for

	2011	2012	2013	2014	2015	2016
Overall Apparent Nest Success	30%	54%	40%	64%	52%	36%
Total Number of Nests	102	91	85	74	77	85
Number of 1st Nests / Nest success	79 / 28%	82 / 52%	69 / 39%	68 / 63%	69 / 54%	68 / 35%
Number of 2nd Nests / Nest success	22 / 41%	9 / 67%	15 / 40%	6 / 67%	8 / 38%	17 / 41%
Number of 3rd Nests / Nest success	1 / 0%	–	1 / 100%	–	–	–

Table 4. Apparent nest success (number of monitored nests that hatched at least one chick / total number of nests monitored) of our marked population of greater sage-grouse hens in Golden Valley and Mussellshell Counties, Montana during 2011 – 2015 (SGI and Non-SGI areas combined). Total number of nests monitored are presented as well as number of nests per nest attempt. Nest success for 1st nests = # successful 1st nests / total 1st nests attempted; 2nd nests = # successful 2nd nests / total 2nd nests attempted; 3rd nests = # successful 3rd nests / total 3rd nests attempted.

	2011	2012	2013	2014	2015
Total number of marked hens at the start of the nesting season	101	112	93	106	100
Hens attempting to nest out of all marked hens	78% (79/101)	73% (82/112)	76% (71/93)	64% (68/106)	66% (66/100)

Table 5. Percent of our marked population of greater sage-grouse hens that attempted at least one nest in Golden Valley and Mussellshell Counties, Montana during 2011 – 2015 (SGI and Non-SGI areas combined).

individual females, as we monitored from one up to seven nests for each female (all nests for an individual from 2011-2015) and fates of nests from the same female may not be independent if females differ in 'quality' with respect to their ability to successfully incubate a nest.

Of the 11 variables passed to the final model only precipitation was supported with a Bayes factor ≥ 3, with greater amounts of rainfall over a 4-day period associated with lower daily nest survival (Fig. 6). Distance from county roads and highways received some support from a 95% credible interval that did not overlap zero, suggesting greater survival farther from these features. Grazing system (Non-SGI vs SGI), presence or absence of livestock in the pasture during nesting, current year's grazing intensity, and density of previous-years' cow pats were all unrelated to daily nest survival.

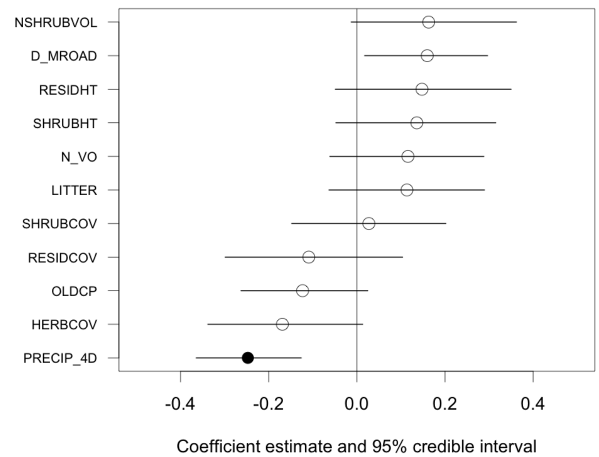


Figure 6. Coefficient estimates from logistic regression model describing variables influencing daily nest survival of sage-grouse nests (n=412) in Golden Valley and Musselshell Counties, Montana during 2011 to 2015. Filled circles identify important variables supported by Bayes factors and error bars represent 95% credible intervals.

Nest success varies from 14 – 86% across the entire range of sage-grouse (including studies from Oregon, Colorado, and Idaho; Connelly et al. 2004). The average nest success across the range is 46% (Connelly et al. 2011). Nest success observed during all years of our study is within the range expected for sage-grouse.

Chick Survival: 2011 – 2016

Consistent monitoring of females that are initiating nests makes it possible to estimate hatch dates to within one day. Sage-grouse chicks of marked hens are captured by hand 2 to 8 days after hatching, with most captured no later than 5 days old. We capture the entire broods of these hens by homing in on the hen with telemetry just after sunset when the hen broods all of the chicks underneath her, allowing us to get close enough to capture the chicks. The hen usually flushes or walks away a short distance, remaining within 50 – 100 m throughout the entire process, collecting her chicks after they are released. The chicks are captured and placed into a cooler containing a hot water bottle that keeps them warm while we are working. We affix a 1.3 g backpack VHF radio transmitter (Model A1065, Advanced Telemetry Systems, Isanti, MN) to 2 randomly selected chicks per brood (mean number of chicks hatched per nest is six to seven; Tack 2009) via two small sutures on the lower back (similar to the suture technique described in Dreitz et al. [2011]). This method is the most successful (<1% accidental death rate) and common method used to attach radio transmitters to sage-grouse chicks (Burkepile et al. 2002, Dahlgren et al. 2010) and has been successful with other galliforms (Dreitz et al. 2011). The mean weights (SE) of 2 to 5 day old chicks on our study range from 41.6 g (SE = 0.86) to 51.7 (SE = 2.2), respectively. A 1.3 g radio transmitter lasts 49 to 98 days and is 3.1% of the body weight of a 2d old chick and 2.5% of a 5 d old chick. The tagging procedure typically lasts 20 – 30 min per brood, and then we release all chicks together under sagebrush cover. We monitor the hen to ensure she is nearby when we release the chicks, and follow-up the next morning to monitor chick survival and determine if the hen and chicks are still together. We monitor chicks every other day for the first two weeks, and at least twice per week thereafter until the chicks die or their tags expire or they are fitted with an adult transmitter.

Annual apparent survival estimates (number of chicks known to be alive at the end of the monitoring period / number of total marked chicks at the start of the monitoring period) for sage-grouse chicks during 2011 – 2016 ranged from 12 – 22% (Table 6). We are still cleaning up data, thus these are preliminary results that may be adjusted.

	2011	2012	2013	2014	2015	2016
Apparent Chick Survival	22%	10%	14%	12%	19%	22%
Number Surviving Chicks	5	8	8	9	11	10
Total Number of Marked Chicks	23	81	57	75	58	45

Table 6. Apparent survival of greater sage-grouse chicks (number of chicks known to be alive at the end of the monitoring period / number of total marked chicks at the start of the monitoring period) in Golden Valley and Musselshell Counties, Montana during 2011 – 2016 that were known to survive until their transmitter battery failed or were recaptured to be marked with an adult transmitter.

Only chicks that were known to survive until their transmitter battery expired or were recaptured to be marked with an adult transmitter were considered to survive until the end of the monitoring period. These estimates are conservative because chicks whose signals were lost and their fates unknown were not considered alive for these estimates. The monitoring period for the "Number of Surviving Chicks" is defined as the number of chicks that survived at least 75 days, when they were large enough to be recaptured and marked with an adult radio transmitter (if female; we only mark female adults in this study). If chicks survived and were not recaptured, their monitoring period was up to 100 days.

We used package "survival" (Therneau 2016) in program R to run the following Kaplan-Meier survival analyses. With data pooled across years, the Kaplan-Meier mean survival time for sage-grouse chicks marked with radio transmitters during 2011 – 2015 was 25 d (SE = 2.67 d), and the median survival time was 13 d (95% confidence interval [CI] = 10 – 16 d; Fig. 7). Individuals whose signals are lost or fates are unknown are censored from the

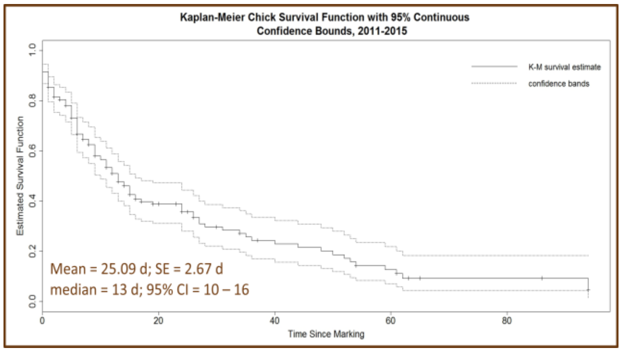


Figure 7. Kaplan-Meier survival curve and 95% confidence bounds for greater sage-grouse chicks marked with radio transmitters in Golden Valley and Musselshell Counties, Montana, USA during 2011 – 2015. Mean survival time for marked chicks was 25 days (SE = 2.67 days), while the median survival time was 13 days (95% confidence interval = 10 – 16 days).

analysis at the last time they were successfully monitored. Thus our Kaplan-Meier survival estimates are conservative.

In the following preliminary analyses, we used log-rank tests to look for differences in survival of marked chicks related to year (2011 – 2015) or grazing treatment of the pastures where chicks hatched (SGI or Non-SGI). Chick survival was not significantly different among years ($\chi^2 = 5$, $df = 4$, $p = 0.292$; Fig. 8). The SGI status of the pastures in which chicks hatched did not impact chick survival during any part of the monitoring period when data for all years was pooled ($\chi^2 = 0.5$, $df = 2$, $p = 0.784$) or when evaluating SGI-status with respect to year (log-rank test stratified by year: $\chi^2 = 3.1$, $df = 2$, $p = 0.21$). However, this is only a first look at where chicks spend their first few days post-hatch. Chicks may move between SGI and Non-SGI pastures throughout the monitoring period, and a different analysis is needed to estimate survival instantaneously during each monitoring interval throughout the period as well as allow the grazing status of the pastures to also change throughout

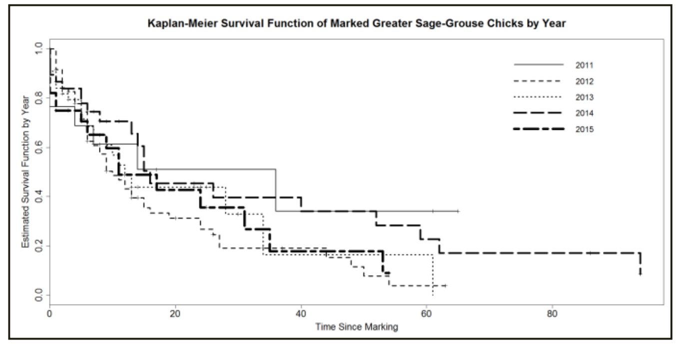


Figure 8. Kaplan-Meier survival curve by year for greater sage-grouse chicks marked with radio transmitters in Golden Valley and Musselshell Counties, Montana, USA during 2011 – 2015. The 95% confidence bounds are not shown in order to make the survival curves easy to see. Chick survival was not different among years ($\chi^2 = 5$, df = 4, p = 0.292).

each interval of the monitoring period. These analyses will be completed outside the period covered by this agreement.

Weather conditions during the sensitive post-hatch time, which peaks in early June for many prairie grouse, may have a large impact on chick survival (Flanders-Wanner et al. 2004). For example, chicks cannot thermoregulate during their first week post-hatch and rely on the hen to keep them warm. Many chicks get chilled and die during heavy rain events during the post-hatch period (Horak and Applegate 1998). We have not yet formally analyzed the effects of weather and other habitat variables on chick survival. Previous studies have shown chick survival to be variable and range from 12-50% during the first few weeks after hatching (Aldridge and Boyce 2007, Gregg et al. 2009, Dahlgren et al. 2010, Guttery et al. 2013). However, caution should be used when comparing estimates among studies because the duration of monitoring periods differ. For example, Gregg et al. (2009) and Dahlgren et al (2010) monitored sage-grouse chicks for 28 and 42 days, respectively, whereas we are able to monitor chicks up to 110 days due to the recent availability of smaller, lighter radio transmitters with longer battery life. In addition, some studies measure "brood" survival (at least one chick from a brood lives until the end of the monitoring period) or unmarked chicks rather than monitoring individually marked chicks. Unmarked chicks are difficult to observe and monitor, and brood mixing may occur that results in broods containing chicks not parented by a particular hen. Thus there are limitations when comparing unmarked chick or brood survival estimates with telemetry survival estimates.

The low chick survival observed during our study suggests a focus for future research and conservation efforts. We are working on chick resource selection and survival analyses to determine how habitat variables impact survival and resource selection in order to help guide management for this life phase. We are also evaluating hen survival, nest success, chick survival, and the habitat needs for these life phases together to identify priority areas for conservation efforts.

INSECTS

By: Hayes Goosey, Montana State University

The Refuge was sampled with pitfall traps during the mid to late sage-grouse brooding period during 2014 and 2015. Arthropods were identified to Family with a total of 7,730 specimens collected on the Refuge thus far. Sweep net samples taken in 2013 and 2014 are still being processed.

A Simpson's (1-D) diversity index was calculated for the Refuge and compared against diversities associated with Sage-Grouse Initiative (SGI) pastures which were either 'Grazed' or 'Deferred' during the sage-grouse early brooding time period. The Simpson's (1-D) index ranges from 0 – 1 and represents the probability that two individuals randomly selected from a sample will belong to different Families. The closer the number is to 1, the more diverse the sample. Comparisons were calculated using a Diversity Permutation test which compares the diversities using random permutations and provides a *p-value* representing the probability that the diversities are statistically similar. Results are presented in Table 7.

LMWR	**Grazed**	**Deferred**	***p-value***
0.86	0.89	---	<0.01
0.86	---	0.88	<0.01
---	0.89	0.88	<0.01

Table 7. Simpson's 1-D diversity indices for the Lake Mason National Wildlife Refuge (LMWR) and Sage-Grouse Initiative Grazed and Deferred pastures with Diversity Permutation p-values which indicate the probability that the diversity values within the same row are statistically similar.

Additionally, a Detrended Correspondence Analysis (DCA) was performed to elucidate any influence various land management practices may have on the structure of the invertebrate community. DCA is a weighted-average technique that reciprocally double-transforms and detrends non-linear community data to produce 'corresponding' sampling unit ordination. Results of this technique indicate that the arthropod community structure differs both spatially and temporally across sampling location and year (Fig. 9).

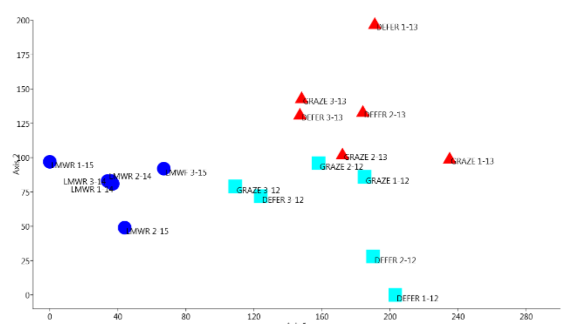


Figure 9. Detrended Correspondence Analysis of Lake Mason National Wildlife Refuge (hereafter Refuge) and Sage-Grouse Initiative (SGI) pastures where livestock were either present (Graze) or absent (Defer) during the sage-grouse early brooding period. Numbers following letter designations represent the sampling location and year, respectively. Blue circles represent samples taken on the Refuge during 2014 and 2015. Light blue squares represent samples taken during 2012 on SGI Graze and Defer pastures. Red triangles represent SGI Graze and Defer pastures during 2013. Spatially, the community structure of the Refuge is distinct from that sampled on SGI pastures (blue circles vs. non-blue

circles); however, temporally this location displays much similarity suggesting that the arthropod community structure and abundances were similar over both sampling years. Within the SGI system, there is some indication of spatial similarity among grazed and rested pastures; however, the strongest ecological separation is evident between years regardless of pasture designation (light blue squares versus red triangles).

Sampling at the Refuge recorded little temporal variation suggesting that the arthropod community was composed of similar Families in similar abundances during both sampling years; however the Refuge (blue circles) over sampling year has a distinct spatial community structure when compared to the SGI Grazed and Deferred pastures (non-blue circles). Within the SGI system, the most notable distinction is temporal variation between sampling years (light blue squares vs. red triangles) with minimal grouping being displayed spatially either within or across year. Further analyses of these data are forthcoming and will continue to elucidate the influences of dominant land uses practices, such as livestock grazing or long-term rest, on the abundance and community structure of rangeland arthropods in central Montana.

PROFESSIONAL ACTIVITIES COMPLETED

- Submitted a manuscript based on nest success and nest site selection results: Smith, J., J. Tack, L. Berkeley, M. Szczypinski, D. Naugle. 2016. Effects of livestock grazing, weather, and landscape on nesting greater sage-grouse. Journal of Wildlife Management. In press.
- Landowner appreciation dinner, Roundup, MT, July 29, 2016.
- Invited presentation at the National SGI SWAT annual training in Lewistown, MT Jun 27-29, 2016 to several agency representatives from USFWS, BLM, NRCS, etc as well as the SGI SWAT biologists working in all states across the range of sage-grouse.
- Invited presentation to the Yellowstone Valley Audubon in Billings, MT, April 18, 2016.
- Invited presentation to Wildlife Conservation class at Rocky Mountain College, Billings, MT, Mar 23, 2016.
- Invited presentation on our sage-grouse grazing project at the Sagebrush Conservation Conference in Salt Lake City, Utah, Feb 25, 2016.
- Hosted annual oversight committee meeting Feb 9, 2016.
- Provided annual and biannual progress reports to funders: BLM, FWP, and Intermountain West Joint Venture and Pheasants Forever (final report).
- Provided updates to private landowners and our oversight committee.

ACTIVITIES FOR THE NEXT YEAR

We are currently preparing to hire our seasonal field crew for the 2017 season and will begin trapping hens in March 2017. We will continue monitoring hen survival, nest success, chick survival, and habitat use during 2016 – 2017. We will continue sampling plots on Lake Mason satellite Refuge units in 2017. We will continue to work on analyses and to communicate the progress of our study to landowners, our oversight committee, and partners/funders via regular communication and formal written updates. We will host the annual oversight committee meeting in Helena during February 2017.

LITERATURE CITATION

Aldridge, C. L., and M. S. Boyce. 2007. Linking occurrence and fitness to persistence: habitat-based approach for endangered greater sage-grouse. Ecological Applications 17:508-526.

Aldridge, C. L., and R. M. Brigham. 2001. Nesting and reproductive activities of greater sage-grouse in a declining northern fringe population. Condor 103.

Bates, D., M. Maechler, B. Bolker, and S. Walker. 2015. Fitting Linear Mixed-Effects Models Using lme4. Journal of Statistical Software **67**:1-48.

Blomberg, E. J., J. S. Sedinger, D. V. Nonne, and M. T. Atamian. 2013. Seasonal reproductive costs contribute to reduced survival of female greater sage-grouse. Journal of Avian Biology 44:149-158.

Burkepile, N. A., J. W. Connelly, D. W. Stanley, and K. P. Reese. 2002. Attachment of radiotransmitters to one-day-old sage-grouse chicks. Widlife Society Bulletin 30:93-96.

Canfield, R. H. 1941. Application of the line interception method in sampling range vegetation. Journal of Forestry 39:388-394.

Connelly, J. W., C. A. Hagen, and M. A. Schroeder. 2011. Characteristics and dynamics of greater sage-grouse populations. Pages 53-67 *in* S. T. Knick, andJ. W. Connelly, editors. Greater sage-grouse: ecology and conservation of a landscape species and its habitat. Studies in Avian Biology (vol. 38). University of California Press, Berkeley, California, USA.

Connelly, J. W., S. T. Knick, M. A. Schroeder, and S. J. Stiver. 2004. Conservation assessment of greater sage-grouse and sagebrush habitats. Unpublished report. Western Association of Fish and Wildlife Agencies, Cheyenne, Wyoming, USA.

Connelly, J. W., K. P. Reese, and M. A. Schroeder. 2003. Monitoring of greater sage-grouse habitats and populations. College of Natural Resources Experiment Station Bulletin 80. University of Idaho, Moscow, Idaho, USA.

Connelly, J. W., K. P. Reese, W. L. Wakkinen, M. D. Robertson, and R. A. Fischer. 1994. Sage grouse ecology. Study I: sage grouse response to controlled burn. Idaho Department of Fish and Game.

Cooch, E. and G. White. 2013. Program MARK: a gentle introduction. 12th edition. Ithaca, New York, USA.

Dahlgren, D. K., T. A. Messmer, and D. N. Koons. 2010. Achieving better estimates of greater sage-grouse habitat. Journal of Range Management 74:1286-1294.

Daubenmire, R. 1959. A canopy-coverage method of vegetational analysis. Northwest Science 33:43-64.

Doherty, K. E. 2008. Sage-grouse and energy development: integrating science with conservation planning to reduce impacts., Ph.D. Dissertation, The University of Montana, Missoula, Montana.

Doherty, K. E., D. E. Naugle, and B. L. Walker. 2010. Greater sage-grouse nesting habitat: the importance of managing at multiple scales. Journal of Wildlife Management 74:1544-1553.

Dreitz, V. J., L. A. Baeten, T. Davis, and M. M. Riordan. 2011. Testing radiotransmitter attachment techniques on northern bobwhite and chukar chicks. Wildlife Society Bulletin 35:475-480.

Dreitz, V. J., J. Golding, and A. Harrington. 2015. Assessing land use practices on the ecological characteristics of sagebrush ecosystems: multiple migratory bird responses. Final Report submitted to the United States Fish and Wildlife Service Plains and Prairie Pothole Landscape Conservation Initiative; *in conjunction* with the Bureau of Land Management and Montana Fish, Wildlife and Parks upon completion of funding. The University of Montana, Wildlife Biology Program and Avian Science Center, College of Forestry and Conservation, Missoula, Montana, 16 pp.

Flanders-Wanner, B. L., G. C. White, and L. L. McDaniel. 2004. Weather and prairie grouse: dealing with effects beyond our control. Wildlife Society Bulletin 32:22-34.

Giesen, K. M., T. J. Schoenberg, and C. E. Braun. 1982. Methods for trapping sage grouse in Colorado. Wildlife Society Bulletin 10:224-231.

Gillen, R. L. and P. L. Sims. 2006. Stocking Rate and Weather Impacts on Sand Sagebrush and Grasses: A 20-Year Record. Rangeland Ecology and Management, 59:145-152.

Gregg, M. A., M. R. Dunbar, and J. A. Crawford. 2007. Use of implanted radiotransmitters to estimate survival of sage-grouse chicks. Journal of Wildlife Management 71:646-651.

Guttery, M. R., D. K. Dahlgren, T. A. Messmer, J. W. Connelly, K. P. Reese, P. A. Terletzky, N. Burkepile, and D. N. Koons. 2013. Effects of landscape-scale environmental variation on greater sage-grouse chick survival. PLOS ONE 8:1-11.

Holloran, M. J. 2005. Greater sage-grouse (*Centrocercus urophasianus*) population response to natural gas field development in western Wyoming. Ph.D. Dissertation, University of Wyoming, Laramie, Wyoming.

Horak, G. J., and R. D. Applegate. 1998. Greater prairie chicken management. Kansas School Naturalist 45:3-15.

Kaplan, E. L. and P. Meier. 1958. Nonparametric estimation from incomplete observations. Journal of the American Statistical Association 53:457-481.

Kuo, L. and B. Mallick. 1997. Bayesian semiparametric inference for the accelerated failure-time model. Canadian Journal of Statistics-Revue Canadienne De Statistique 25:457-472.

R Core Team. 2011. R: A Language and Environment for Statistical Computing. Version 2.14.1 (2011--12--22). R Foundation for Statistical Computing, Vienna, Austria. <http://www.R-project.org>

Robel, R. J., J. N. Briggs, A. D. Dayton, and L. C. Hulbert. 1970. Relationships between visual obstruction measurements and weight of grassland vegetation. Journal of Range Management 23:295-297.

Sika, J. L. 2006. Breeding ecology, survival rates, and causes of mortality of hunted and nonhunted greater sage-grouse in central Montana. Masters thesis, Montana State University, Bozeman, Montana, USA.

Taylor, R. L., B. L. Walker, D. E. Naugle, and L. S. Mills. 2012. Managing multiple vital rates to maximize greater sage-grouse population growth. Journal of Wildlife Management 76:336-347.

Therneau, T. M. 2016**.** Survival Analysis, version 2.39-5. June 26, 2016. < https://cran.r-project.org/web/packages/survival/survival.pdf> *Last accessed Aug 5, 2016.*

West, N. E. 2003. History of rangeland monitoring in the USA. Arid Land Research and Management **17**:495-545.